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<p>(54) Title: LOW COMPRESSION, RESILIENT GOLF BALLS INCLUDING AN ORGANOSULFUR CATALYST AND METHOD FOR MAKING SAME</p> <p>(57) Abstract</p> <p>A low compression, resilient golf ball having a center and a cover, made from a polybutadiene reaction product having polybutadiene, a cis-to-trans catalyst including an organosulfur component, and a free radical source. The reaction product has a first dynamic stiffness measured at -50 °C that is less than about 130 percent of a second dynamic stiffness measured at 0 °C. A multi-layer golf ball having a center, at least one intermediate layer disposed concentrically about the center, and a cover. At least a portion of at least one of the center, intermediate layer, or both, are made from a reaction product including polybutadiene having a cis-to-trans catalyst that includes at least one organosulfur component and a free radical source. The reaction product has a first dynamic stiffness measured at -50 °C that is less than about 130 percent of a second dynamic stiffness measured at 0 °C. Addition of various combinations of polybutadiene, cis-to-trans catalyst including at least one organosulfur component, free radical source, filler, and crosslinker, produce golf balls and golf ball components that are resilient (fast) and have low compression (soft).</p>			

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**LOW COMPRESSION, RESILIENT GOLF BALLS INCLUDING
AN ORGANOSULFUR CATALYST AND METHOD FOR MAKING SAME**

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FIELD OF THE INVENTION

The present invention relates to low compression, resilient golf balls and 10 portions thereof formed from the conversion reaction of an amount of polybutadiene, a free radical source, and a cis-to-trans catalyst including at least one organosulfur component at a sufficient reaction temperature to form a polybutadiene reaction product.

BACKGROUND OF THE INVENTION

15 Conventional golf balls can be divided into several general classes: (a) solid golf balls having one or more layers, and (b) wound golf balls. Solid golf balls include one-piece balls, which are easy to construct and relatively inexpensive, but have poor playing characteristics and are thus generally limited for use as range balls. Two-piece balls are constructed with a generally solid core and a cover and are generally the most popular with 20 recreational golfers because they are very durable and provide maximum distance. Balls having a two-piece construction are commonly formed of a polymeric core encased by a cover. Typically, the core is formed from polybutadiene that is chemically crosslinked with zinc diacrylate and/or other similar crosslinking agents. These balls are generally easy to manufacture, but are regarded as having limited playing characteristics. Solid golf balls 25 also include multi-layer golf balls that are comprised of a solid core of one or more layers and/or a cover of one or more layers. These balls are regarded as having an extended range of playing characteristics.

Wound golf balls are generally preferred by many players due to their high spin and soft "feel" characteristics. Wound golf balls typically include a solid, hollow, or 30 fluid-filled center, surrounded by a tensioned elastomeric material and a cover. Wound balls generally are more difficult and expensive to manufacture than solid two-piece balls.

A variety of golf balls designed to provide a wide range of playing characteristics, *i.e.*, the compression, velocity, "feel," and spin, that can be optimized for 35 various playing ability, are known in the prior art. One of the most common polymer components present in modern golf ball construction, in addition to ionomers, is polybutadiene and, more specifically, polybutadiene having a high *cis*- isomer

concentration. The use of a polybutadiene having a high *cis*- concentration results in a very resilient and rigid golf ball, especially when coupled with a hard cover material. These highly resilient golf balls have a relatively hard "feel" when struck by a club. Soft "feel" golf balls constructed with a high *cis*-polybutadiene have low resilience. In an effort to 5 provide improved golf balls, various other polybutadiene formulations have been prepared, as discussed below.

Australian patent document AU-A-16547/97 discloses thread formulations for golf balls including a rubber component, at least one specific diaryl disulfide present in 0.5 to 10 parts by weight of the rubber component and a least one diphenyl disulfide 10 compound, a vulcanizing agent, and an antioxidant. Document AU-A-16548/97 discloses rubber thread having tensile strength of not less than 70% after aging 7 days at 70°C and has a hysteresis loss of not more than 50% and an elongation of less than 1400% formulated with zinc oxide, which preferably includes one or more disulfides when the rubber is high-*cis* polyisoprene.

15 U.S. Patent No. 3,239,228 discloses a solid golf ball having a core molded of polybutadiene rubber with a high sulfur content, and a cover. The polybutadiene content of the core is stereo-controlled to the configuration 25-100 percent *cis*- and 0-65 percent *trans*-1,4-polybutadiene, with any remainder having a vinyl configuration of polybutadiene. A preferred embodiment of the polybutadiene golf ball core contains 35 percent *cis*-, 52 percent *trans*-, and 13 percent vinyl-polybutadiene. The level of *trans*- and vinyl- content 20 are disclosed to be unimportant to the overall playing characteristics of the polymer blend.

British Patent No. 1,168,609 discloses a molding composition from which improved golf ball cores can be molded and which contains *cis*-polybutadiene as a basic polymer component. The core polymer component typically includes at least 60 percent 25 *cis*-polybutadiene, with the remainder being either the *trans*- or vinyl- forms of polybutadiene. In a preferred embodiment, the core polybutadiene component contains 90 percent *cis*- configuration, with the remaining 10 percent being either the *trans*- or vinyl- configurations of 1,4-polybutadiene.

U.S. Patent Nos. 3,572,721 and 3,572,722 disclose a solid, one- or two-piece 30 golf ball, with the two-piece ball having a core and a cover. The cover material can include any one of a number of materials, or blends thereof, known to those of ordinary skill in the art, including *trans*-polybutadiene which may be present in an amount from at least 90 percent, with the remainder being the *cis*- and/or vinyl configuration.

British Patent No. 1,209,032 discloses a two- or three-piece golf ball having 35 a core and a cover. The core or cover material can be any material capable of being crosslinked. In particular, the material can be a polymer or a copolymer of butadiene or

isoprene. Preferably, the polymer component is polybutadiene having a *cis* content of greater than 50 percent by weight.

U.S. Patent No. 3,992,014 discloses a one-piece, solid golf ball. The golf ball material is typically polybutadiene, with a stereo-configuration selected to be at least 60 percent *cis*-polybutadiene, with the remaining 40 percent being the *trans*-polybutadiene and/or 1,2-polybutadiene (vinyl) isomers.

U.S. Patent No. 4,692,497 discloses a golf ball and material thereof formed by curing a diene polymer including polybutadiene and a metal salt of an alpha, beta ethylenically unsaturated acid using at least two free radical initiators.

U.S. Patent No. 4,931,376 discloses a process for producing butadiene polymers for use in various applications, including golf ball cover materials. One embodiment of the invention employs a blended polymeric resin material, including at least 30 percent by weight of a *trans*-polybutadiene polymer as a golf ball cover on a two-piece ball. In a preferred embodiment, the golf ball cover material contains a blend including 30 to 90 percent by weight of a *trans*-polybutadiene polymer.

U.S. Patent No. 4,971,329 discloses a solid golf ball made from a polybutadiene admixture of *cis*-1,4 polybutadiene and 1,2 polybutadiene, a metal salt of an unsaturated carboxylic acid, an inorganic filler, and a free radical initiator. The admixture has about 99.5 percent to about 95 percent by weight of *cis*-1,4 polybutadiene and about 0.5 percent to about 5 percent by weight of 1,2 polybutadiene.

U.S. Patent No. 5,252,652 discloses a one-piece or multi-layered golf ball core with improved flying performance from a rubber composition comprising a base rubber, preferably 1,4-polybutadiene with a *cis*- content of at least 40 mole percent, an unsaturated carboxylic acid metal salt, an organic peroxide, and an organic sulfur compound and/or a metal salt thereof. The organic sulfur compound and/or a metal salt is typically present in an amount from about 0.05 to 2 parts per hundred by weight and the organic peroxide is typically present in an amount from about 0.5 to 3 parts per hundred by weight of the total polymer component.

European Patent No. 0 577 058 discloses a golf ball containing a core and a cover that is formed as two separate layers. The inner layer of the cover is molded over the core and is formed from ionomer resin. The outer layer of the cover is molded over the inner layer and is formed from a blend of natural or synthetic balata and a crosslinkable elastomer, such as polybutadiene. In one embodiment of the outer layer of the cover, the elastomer is 1,4-polybutadiene having a *cis*- structure of at least 40 percent, with the remaining 60 percent being the *trans*- isomer. A preferred embodiment contains a *cis*- structure of at least 90 percent and more preferably, a *cis*- structure of at least 95 percent.

U.S. Patent No. 5,421,580 discloses a wound golf ball having a liquid center contained in a center bag, a rubber thread layer formed on the liquid center, and a cover over the wound layer and liquid center. The cover material can include any one of a number of materials, or blends thereof, known to those of ordinary skill in the art, including 5 *trans*-polybutadiene and/or 1,2-polybutadiene (vinyl), such that the cover has a JIS-C hardness of 70-85; preferred *trans*- percentages are not disclosed.

U.S. Patent No. 5,697,856 discloses a solid golf ball having a core and a cover wherein the core is produced by vulcanizing a base rubber composition containing a butadiene rubber having a *cis*-polybutadiene structure content of not less than 90 percent 10 before vulcanization. The amount of *trans*-polybutadiene structure present after vulcanization is 10 to 30 percent, as amounts over 30 percent are alleged to detrimentally result in cores that are too soft with deteriorated resilience performance, and to cause a decrease in golf ball performance. The core includes a vulcanizing agent, a filler, an organic peroxide, and an organosulfur compound.

15 British Patent No. 2,321,021 discloses a solid golf ball having a core and a cover formed on the core and having a two-layered cover construction having an inner cover layer and an outer cover layer. The outer cover layer is comprised of a rubber composite that contains 0.05 to 5 parts by weight of an organic sulfide compound. The core rubber composition comprises a base rubber, preferably 1,4-polybutadiene having a *cis*- 20 content of at least 40 percent by weight, a crosslinking agent, a co-crosslinking agent, an organic sulfide, and a filler. The crosslinking agent is typically an organic peroxide present in an amount from 0.3 to 5.0 parts by weight and the co-crosslinking agent is typically a metal salt of an unsaturated fatty acid present in an amount from 10 to 40 parts by weight. The organic sulfide compound is typically present from 0.05 to 5 parts by weight.

25 U.S. Patent No. 5,816,944 discloses a solid golf ball having a core and a cover wherein the core has a JIS-C hardness of 50 to 80 and the cover has a Shore-D hardness of 50 to 60. The core material includes vulcanized rubber, such as *cis*-polybutadiene, with a crosslinker, an organic peroxide, an organosulfur compound and/or a metal-containing organosulfur compound, and a filler.

30 Additionally, conventional polymers that have a high percentage of the *trans*-polybutadiene conformation, such as DIENE 35NF, from Firestone Corp., that has 40 percent *cis*- isomer and 50 percent *trans*-polybutadiene isomer, and mixtures of high-*cis*- and high-*trans*- polybutadiene isomers, such as CARIFLEX BR1220, from Shell Corporation, and FUREN 88, from Asahi Chemical Co., respectively, typically do not yield 35 high resilience values and therefore are not desirable.

It is thus desired to prepare golf balls having lower compression, *i.e.*, a softer ball, while having the same or higher resilience than conventional balls. It is alternatively desired to obtain the same or lower compression while achieving greater resilience.

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SUMMARY OF THE INVENTION

All of the embodiments according to the invention below may be used in any golf ball. Particularly, each embodiment may be used in one of the following embodiments. In one embodiment, the golf ball includes a core and a cover disposed concentrically about the core and the reaction product is disposed in at least a portion of the core. In another 10 embodiment, the golf ball includes a core having a center and at least one intermediate layer; and a cover disposed concentrically about the core, wherein the reaction product is disposed in a portion of the core.

The invention relates to a golf ball having a single-layer, dimpled cover disposed about a core, wherein the golf ball includes a material formed from the conversion 15 reaction of an amount of polybutadiene, a free radical source, and a cis-to-trans catalyst including at least one organosulfur component at a sufficient reaction temperature to form a polybutadiene reaction product which includes an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction. In one embodiment, the reaction product still includes a portion of the cis-to-trans catalyst 20 including at least one organosulfur component. In one embodiment, the golf ball includes a cover having at least one of a dimple coverage of greater than about 60 percent, a hardness from about 35 to 80 Shore D, or a flexural modulus of greater than about 500 psi, and wherein the golf ball has at least one of a compression from about 50 to 120 or a coefficient 25 of restitution of greater than about 0.7. In one embodiment, the reaction product has a first dynamic stiffness measured at -50°C that is less than about 130 percent of a second dynamic stiffness measured at 0°C.

In one embodiment, the organosulfur component is substantially free of metal and includes at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido diphenyl disulfide. In a more preferred embodiment, the organosulfur 30 component includes 4,4'-ditolyl disulfide. The cis-to-trans catalyst is typically present in an amount from about 0.1 to 25 parts per hundred of polybutadiene. In a preferred embodiment, the cis-to-trans catalyst is present in an amount from about 0.1 to 12 parts per hundred of polybutadiene. In a more preferred embodiment, the cis-to-trans catalyst is present in an amount from about 0.1 to 8 parts per hundred of polybutadiene. In another 35 embodiment, the cis-to-trans catalyst is present in an amount sufficient to produce the polybutadiene reaction product so as to contain at least about 32 percent *trans*-

polybutadiene isomer. In another embodiment, the cis-to-trans catalyst further comprises at least one of an inorganic sulfide compound, an aromatic organometallic compound, a metal-organosulfur compound, elemental sulfur, a polymeric sulfur, or an aromatic organic compound.

5 In one embodiment, the polybutadiene reaction product includes less than about 7 percent vinyl isomer content based on the total polybutadiene. In a preferred embodiment, the polybutadiene reaction product includes less than about 4 percent vinyl isomer. In a more preferred embodiment, the polybutadiene reaction product includes less than about 2 percent vinyl isomer.

10 In another embodiment where elemental sulfur or polymeric sulfur is included in the cis-to-trans catalyst, the reaction product further includes a vulcanization accelerator, preferably in an amount sufficient to facilitate cis-to-trans conversion. In a preferred embodiment, the vulcanization accelerator includes at least one of sulfenamide, thiazole, dithiocarbamate, thiuram, xanthate, thiadiazine, thiourea, guanidine, or aldehyde-15 amine. The accelerator is typically present in an amount from about 0.05 to 2 phr. In a preferred embodiment, the accelerator is present in an amount from about 0.1 to 1 phr.

20 In one embodiment, the portion of the core having the reaction product is the center. In another embodiment, the center includes a fluid. In yet another embodiment, the intermediate layer may include a wound layer of tensioned elastomeric material. In a preferred embodiment, the tensioned elastomeric material includes the reaction product. In another embodiment, the golf ball further includes a density-modifying filler.

25 The invention also relates to a golf ball having a core with at least two layers and a cover having at least two layers disposed about the core, which golf ball comprises a material formed from a conversion reaction of a sufficient amount of polybutadiene, a free radical source, and a cis-to-trans catalyst comprising at least one organosulfur component, which reaction occurs at a sufficient temperature to form a polybutadiene reaction product, wherein the golf ball includes an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction, and a cis-to-trans catalyst including at least one organosulfur component, wherein the reaction product includes a 30 sphere that has a midpoint having a first hardness and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness.

35 The invention also relates to a method for forming a golf ball having a single-layer, dimpled cover disposed about a core, which includes combining (a) at least one of a cis-to-trans catalyst including at least one organosulfur component, (b) a free radical source, (c) a first resilient polymer component having a *cis*-polybutadiene

component present in an amount greater than about 70 percent of the total polymer component, and optionally, (d) a crosslinking agent, converting a portion of the first resilient polymer component to a second resilient polymer component, wherein at least a portion of the *cis*-polybutadiene component is converted to a *trans*-polybutadiene

5 component and wherein the polybutadiene in the second resilient polymer component comprises a sphere which has a midpoint having a first hardness and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness, and forming the second resilient polymer component into at least a portion of the golf ball.

10 In one embodiment, the portion of the second resilient polymer component is formed into a solid sphere. In another embodiment, which may be alternative or in addition to the forming of the sphere, the portion may be formed into at least one layer disposed about the solid sphere. In the alternative embodiment, the sphere is formed and the portion containing the second resilient polymer component is disposed in at least one layer disposed 15 about the sphere. In the additive embodiment, an additional portion of the second resilient polymer component is formed into a cover disposed concentrically about a sphere.

20 In one embodiment, the polybutadiene component includes *cis*-polybutadiene present in an amount of at least 80 percent of the total first resilient polymer component. In another embodiment, a density-modifying filler is also included in the combining step. In yet another embodiment, the steps of combining the first resilient 25 polymer component and the *cis*-to-*trans* catalyst and forming the portion, includes forming a sphere having a midpoint having a first amount of *trans*-polybutadiene and a surface having a second amount of *trans*-polybutadiene, wherein the first amount is at least about 6 percent less than the second amount.

25 In one embodiment, a portion of the sphere comprises a fluid. In another embodiment, a tensioned elastomeric material is wound about the sphere. In a preferred embodiment, the tensioned elastomeric material includes a reaction product including polybutadiene or polyisoprene and a *cis*-to-*trans* catalyst that includes at least one organosulfur component.

30 In yet another embodiment, the forming includes single- or multi-step compression molding of the first resilient polymer component to convert the first resilient polymer component to the second resilient polymer, and forming the second resilient polymer component into a solid sphere. In a preferred embodiment, the compression molding takes 8 to 15 minutes. In a preferred embodiment, the converting and forming are 35 substantially simultaneous.

The invention also relates to a golf ball having a single-layer, dimpled cover disposed about a core, prepared by a process which includes combining (a) at least one of a cis-to-trans catalyst including at least one organosulfur component, (b) a free radical source, and (c) a first resilient polymer component including a *cis*-polybutadiene component present in an amount greater than about 70 percent of the resilient polymer component, converting a portion of the first resilient polymer component to a second resilient polymer component in about 5 to 18 minutes, wherein at least a portion of the *cis*-isomer content is converted to a *trans*-isomer content and wherein the polybutadiene in the second resilient polymer component is at least about 10 percent *trans*-polybutadiene and less than about 7 percent vinyl-polybutadiene, and forming the second resilient polymer component into at least a portion of the golf ball.

The invention further relates to a golf ball including a material formed from the conversion reaction of a sufficient amount of polybutadiene, a free radical source, and a cis-to-trans catalyst including at least one organosulfur component, which reaction occurs at a sufficient reaction temperature to form a polybutadiene reaction product which includes an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction and a cis-to-trans catalyst including at least one organosulfur component, wherein the reaction product includes a sphere which has a midpoint having a first hardness and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness.

The invention also relates to a golf ball formed from the conversion reaction of an amount of polybutadiene, a free radical source, and a cis-to-trans catalyst including at least one organosulfur component, which reaction occurs at a sufficient temperature to form a polybutadiene reaction product which includes an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction, and a cis-to-trans catalyst including at least one organosulfur component, wherein the reaction product has a first dynamic stiffness measured at -50°C that is less than about 130 percent of a second dynamic stiffness measured at 0°C.

The golf ball may also be prepared by combining (a) a cis-to-trans catalyst including at least one organosulfur component, (b) a free radical source, and (c) a first resilient polymer component including a *cis*-polybutadiene component present in an amount greater than about 70 percent of the total polymer, converting a portion of the first resilient polymer component to a second resilient polymer component in about 5 to 18 minutes at a sufficient temperature to convert at least a portion of the *cis*-polybutadiene component to a *trans*-polybutadiene component and wherein the polybutadiene in the second resilient polymer component is at least about 10 percent *trans*-polybutadiene and less than about 7

percent vinyl-polybutadiene, and forming the second resilient polymer component into at least a portion of the golf ball, wherein the second resilient component includes a sphere which has a midpoint having a first hardness and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness.

5 The golf ball may also be prepared by combining at least (a) a cis-to-trans catalyst including at least one organosulfur component, (b) a free radical source, and (c) a first resilient polymer component including a *cis*-polybutadiene component present in an amount greater than about 70 percent of the total polymer component, converting a portion 10 of the first resilient polymer component to a second resilient polymer component in about 5 to 18 minutes at a sufficient temperature to convert at least a portion of the *cis*-polybutadiene component to a *trans*-polybutadiene component and wherein the polybutadiene in the second resilient polymer component is at least about 10 percent *trans*-polybutadiene and less than about 7 percent vinyl-polybutadiene, and forming the second 15 resilient polymer component into at least a portion of the golf ball, wherein the second resilient component has a first dynamic stiffness measured at -50°C that is less than about 130 percent of a second dynamic stiffness measured at 0°C.

The invention also relates to a golf ball including a material formed from the conversion reaction of a sufficient amount of polybutadiene, a free radical source, and a cis-20 to-trans catalyst comprising at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido diphenyl disulfide, which reaction occurs at a sufficient temperature to form a polybutadiene reaction product and which golf ball includes an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion 25 reaction, and a cis-to-trans catalyst including at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido diphenyl disulfide.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the invention can be ascertained from the following detailed description that is provided in connection with the drawing(s) described 30 below:

Fig. 1 is a cross-sectional view of a two-piece golf ball having a cover and a core according to the invention.

Fig. 2 is a cross-section of a golf ball having an intermediate layer between a cover and a center according to the invention.

35 Fig. 3 is a cross-section of a golf ball having more than one intermediate layer between a cover and a center according to the invention.

DEFINITIONS

The term "about," as used herein in connection with one or more numbers or numerical ranges, should be understood to refer to all such numbers, including all numbers in a range.

As used herein, the term "active ingredients" is defined as the specific components of a mixture or blend that are essential to the chemical reaction.

As used herein, substituted and unsubstituted "aryl" groups means a hydrocarbon ring bearing a system of conjugated double bonds, typically comprising $4n + 2$ π (pi) ring electrons, where n is an integer. Examples of aryl groups include, but are not limited to phenyl, naphthyl, anisyl, tolyl, xylenyl and the like. According to the present invention, aryl also includes heteroaryl groups, e.g., pyrimidine or thiophene. These aryl groups may also be substituted with any number of a variety of functional groups. In addition to the functional groups described herein in connection with carbocyclic groups, functional groups on the aryl groups can include nitro groups.

As used herein, the term "Atti compression" is defined as the deflection of an object or material relative to the deflection of a calibrated spring, as measured with an Atti Compression Gauge, that is commercially available from Atti Engineering Corp. of Union City, NJ. Atti compression is typically used to measure the compression of a golf ball.

When the Atti Gauge is used to measure cores having a diameter of less than 1.680 inches, it should be understood that a metallic or other suitable shim is used to make the measured object 1.680 inches in diameter. However, when referring to the compression of a core, it is preferred to use a compressive load measurement. The term "compressive load" is defined as the normalized load in pounds for a 10.8-percent diametrical deflection for a spherical object having a diameter of 1.58 inches.

As used herein, substituted and unsubstituted "carbocyclic" means cyclic carbon-containing compounds, including, but not limited to cyclopentyl, cyclohexyl, cycloheptyl, adamantyl, and the like. Such cyclic groups may also contain various substituents in which one or more hydrogen atoms has been replaced by a functional group.

Such functional groups include those described above, and lower alkyl groups having from 1-28 carbon atoms. The cyclic groups of the invention may further comprise a heteroatom.

As used herein, the term "coefficient of restitution" for golf balls is defined as the ratio of the rebound velocity to the inbound velocity when balls are fired into a rigid plate. The inbound velocity is understood to be 125 ft/s.

As used herein, the term "dynamic stiffness" is defined as load divided by the deflection for a 1.4-mm spherical radius penetration probe oscillating at 1 Hz with an

amplitude of 100 μm . The probe dynamically penetrates the surface of a sample material. Material samples of spherical cores were prepared by sectioning out a 6-mm-thick layer along the equator of core to produce a disk 6 mm thick with one surface containing the center of the core. By positioning the probe at any selected radial position on the disk, a 5 dynamic stiffness measurement may be obtained. Accurate dynamic measurements may be made by keeping the material sample at a substantially uniform temperature. The dynamic stiffness was acquired using a Dynamic Mechanical Analyzer, Model DMA 2980 available from TA Instruments Corporation of New Castle, Delaware. The instrument setting for the DMA 2980 were 1-Hz frequency, 100- μm amplitude, 0.3-N static load, and auto strain of 10 105 percent. The 1.4-mm spherical radius probe is available from TA Instruments as a penetration kit accessory to the DMA 2980. The DMA 2980 is equipped with a temperature-controlled chamber that enables testing at a wide variety of ambient temperatures.

As used herein, the terms "Group VIA component" or "Group VIA element" 15 mean a component that includes a sulfur component, a selenium component, or a tellurium component, or a combination thereof.

As used herein, the term "fluid" includes a liquid, a paste, a gel, a gas, or any combination thereof.

As used herein, the term "loss tangent," or $\tan \delta$, is defined as unrecoverable 20 energy divided by recoverable energy, where the energy of deflection is measured at the operating criteria specified herein for dynamic stiffness. The loss tangent was acquired using the same Dynamic Mechanical Analyzer and setting as above.

As used herein, the term "molecular weight" is defined as the absolute weight average molecular weight.

25 As used herein, the term "multilayer" means at least two layers and includes liquid center balls, wound balls, hollow-center balls, and balls with at least two intermediate layers and/or an inner or outer cover.

As used herein, the term "parts per hundred", also known as "phr", is defined as the number of parts by weight of a particular component present in a mixture, relative to 30 100 parts by weight of the total polymer component. Mathematically, this can be expressed as the weight of an ingredient divided by the total weight of the polymer, multiplied by a factor of 100.

As used herein, the term "substantially free" means less than about 5 weight percent, preferably less than about 3 weight percent, more preferably less than about 1 35 weight percent, and most preferably less than about 0.01 weight percent.

As used herein, the term "sulfur component" means a component that is elemental sulfur, polymeric sulfur, or a combination thereof. It should be further understood that "elemental sulfur" refers to the ring structure of S₈ and that "polymeric sulfur" is a structure including at least one additional sulfur relative to the elemental sulfur.

5

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to one-piece golf balls and two piece golf balls having a core and a cover, or multilayer golf balls having a solid, hollow, or fluid-filled center, at least one intermediate layer disposed concentrically adjacent to the center, and a 10 cover. At least one of the center, cover, or intermediate layer includes a reaction product that includes a cis-to-trans catalyst, a resilient polymer component having polybutadiene, a free radical source, and optionally, a crosslinking agent, a filler, or both. Preferably, the reaction product has a first dynamic stiffness measured at -50°C that is less than about 130 percent of a second dynamic stiffness measured at 0°C. More preferably, the first dynamic 15 stiffness is less than about 125 percent of the second dynamic stiffness. Most preferably, the first dynamic stiffness is less than about 110 percent of the second dynamic stiffness.

The invention also includes a method to convert the *cis*- isomer of polybutadiene to the *trans*- isomer during a molding cycle and to form a golf ball. Various combinations of polymers, cis-to-trans catalysts, fillers, crosslinkers, and a source of free 20 radicals, may be used. To obtain a higher resilience and lower compression, a high-molecular weight polybutadiene with a *cis*- isomer content preferably greater than about 70 percent is converted to increase the percentage of *trans*- isomer content at any point in the golf ball or portion thereof, preferably to increase the percentage throughout substantially 25 all of the golf ball or portion thereof, during the molding cycle. More preferably, the *cis*- polybutadiene isomer is present in an amount of greater than about 80 percent of the total polybutadiene content. Most preferably, the *cis*-polybutadiene isomer is present in an amount of greater than about 96 percent of the total polybutadiene content. Without wishing to be bound by any particular theory, it is believed that a low amount of 1,2-polybutadiene isomer ("vinyl-polybutadiene") is desired in the initial polybutadiene, and the 30 reaction product. Typically, the vinyl polybutadiene isomer content is less than about 7 percent. Preferably, the vinyl polybutadiene isomer content is less than about 4 percent. More preferably, the vinyl polybutadiene isomer content is less than about 2 percent. Without wishing to be bound by any particular theory, it is also believed that the resulting mobility of the combined *cis*- and *trans*-polybutadiene backbone is responsible for the 35 lower modulus and higher resilience of the reaction product and golf balls including the same.

To produce a polymer reaction product that exhibits the higher resilience and lower modulus (low compression) properties that are desirable and beneficial to golf ball playing characteristics, high-molecular-weight *cis*-1,4-polybutadiene, preferably may be converted to the *trans*- isomer during the molding cycle. The polybutadiene material 5 typically has a molecular weight of greater than about 200,000. Preferably, the polybutadiene molecular weight is greater than about 250,000, more preferably between about 300,000 and 500,000. Without wishing to be bound by any particular theory, it is believed that the *cis*-to-*trans* catalyst component, in conjunction with the free radical source, acts to convert a percentage of the polybutadiene polymer component from the *cis*- to the 10 *trans*- conformation. The *cis*-to-*trans* conversion requires the presence of a *cis*-to-*trans* catalyst, such as an organosulfur or metal-containing organosulfur compound, a substituted or unsubstituted aromatic organic compound that does not contain sulfur or metal, an inorganic sulfide compound, an aromatic organometallic compound, or mixtures thereof. As used herein, “*cis*-to-*trans* catalyst” means any component or a combination thereof that 15 will convert at least a portion of *cis*-polybutadiene isomer to *trans*-polybutadiene isomer at a given temperature. The *cis*-to-*trans* catalyst component may include one or more of the other *cis*-to-*trans* catalysts described herein, but must include at least one organosulfur component.

In one embodiment, the at least one organosulfur component is substantially 20 free of metal, which typically means less than about 10 weight percent metal, preferably less than about 3 weight percent metal, more preferably less than about 1 weight percent metal, and most preferably only trace amounts of metal, such as less than about 0.01 weight percent.

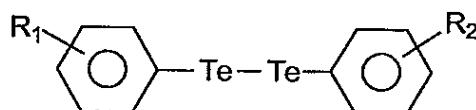
As used herein when referring to the invention, the term “organosulfur 25 compound(s)” or “organosulfur component(s),” means at least one of 4,4'-diphenyl disulfide; 4,4'-diphenyl acetylene, 4,4'-ditolyl disulfide; 2,2'-benzamido diphenyl disulfide; bis(2-aminophenyl) disulfide; bis(4-aminophenyl) disulfide; bis(3-aminophenyl) disulfide; 2,2'-bis(4-aminonaphthyl) disulfide; 2,2'-bis(3-aminonaphthyl) disulfide; 2,2'-bis(4-aminonaphthyl) disulfide; 2,2'-bis(5-aminonaphthyl) disulfide; 2,2'-bis(6-aminonaphthyl) 30 disulfide; 2,2'-bis(7-aminonaphthyl) disulfide; 2,2'-bis(8-aminonaphthyl) disulfide; 1,1'-bis(2-aminonaphthyl) disulfide; 1,1'-bis(3-aminonaphthyl) disulfide; 1,1'-bis(3-aminonaphthyl) disulfide; 1,1'-bis(4-aminonaphthyl) disulfide; 1,1'-bis(5-aminonaphthyl) disulfide; 1,1'-bis(6-aminonaphthyl) disulfide; 1,1'-bis(7-aminonaphthyl) disulfide; 1,1'-bis(8-aminonaphthyl) disulfide; 1,2'-diamino-1,2'-dithiodinaphthalene; 2,3'-diamino-1,2'-dithiodinaphthalene; bis(4-chlorophenyl) disulfide; bis(2-chlorophenyl) disulfide; bis(3-chlorophenyl) disulfide; bis(4-bromophenyl) disulfide; bis(2-bromophenyl) disulfide; bis(3- 35 chlorophenyl) disulfide;

bromophenyl) disulfide; bis(4-fluorophenyl) disulfide; bis(4-iodophenyl) disulfide; bis(2,5-dichlorophenyl) disulfide; bis(3,5-dichlorophenyl) disulfide; bis(2,4-dichlorophenyl) disulfide; bis(2,6-dichlorophenyl) disulfide; bis(2,5-dibromophenyl) disulfide; bis(3,5-dibromophenyl) disulfide; bis(2-chloro-5-bromophenyl) disulfide; bis(2,4,6-trichlorophenyl) disulfide; bis(2,3,4,5,6-pentachlorophenyl) disulfide; bis(4-cyanophenyl) disulfide; bis(2-cyanophenyl) disulfide; bis(4-nitrophenyl) disulfide; bis(2-nitrophenyl) disulfide; 2,2'-dithiobenzoic ethyl; 2,2'-dithiobenzoic methyl; 2,2'-dithiobenzoic acid; 4,4'-dithiobenzoic ethyl; bis(4-acetylphenyl) disulfide; bis(2-acetylphenyl) disulfide; bis(4-formylphenyl) disulfide; bis(4carbamoylphenyl) disulfide; 1,1'-dinaphthyl disulfide; 2,2'-dinaphthyl disulfide; 1,2'-dinaphthyl disulfide; 2,2'-bis(1-chlorodinaphthyl) disulfide; 2,2'-bis(1-bromonaphthyl) disulfide; 1,1'-bis(2-chloronaphthyl) disulfide; 2,2'-bis(1-cyanonaphthyl) disulfide; 2,2'-bis(1-acetylnaphthyl) disulfide; and the like; or a mixture thereof. Preferred organosulfur components include 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido diphenyl disulfide, or a mixture thereof. A more preferred organosulfur component includes 4,4'-ditolyl disulfide. The organosulfur *cis*-to-*trans* catalyst, when present, is preferably present in an amount sufficient to produce the reaction product so as to contain at least about 12 percent *trans*-polybutadiene isomer, but typically is greater than about 32 percent *trans*-polybutadiene isomer based on the total resilient polymer component. Suitable metal-containing organosulfur components include, but are not limited to, cadmium, copper, lead, and tellurium analogs of diethyldithiocarbamate, diamyldithiocarbamate, and dimethyldithiocarbamate, or mixtures thereof. Suitable substituted or unsubstituted aromatic organic components that do not include sulfur or a metal include, but are not limited to, 4,4'-diphenyl acetylene, azobenzene, or a mixture thereof. The aromatic organic group preferably ranges in size from C₆ to C₂₀, and more preferably from C₆ to C₁₀. Suitable inorganic sulfide components include, but are not limited to titanium sulfide, manganese sulfide, and sulfide analogs of iron, calcium, cobalt, molybdenum, tungsten, copper, selenium, yttrium, zinc, tin, and bismuth. The *cis*-to-*trans* catalyst may also be a blend of an organosulfur component and an inorganic sulfide component.

30 A substituted or unsubstituted aromatic organic compound may also be included in the *cis*-to-*trans* catalyst. In one embodiment, the aromatic organic compound is substantially free of metal. Suitable substituted or unsubstituted aromatic organic components include, but are not limited to, components having the formula (R₁)_x-R₃-M-R₄-(R₂)_y, wherein R₁ and R₂ are each hydrogen or a substituted or unsubstituted C₁₋₂₀ linear, branched, or cyclic alkyl, alkoxy, or alkylthio group, or a single, multiple, or fused ring C₆ to C₂₄ aromatic group; x and y are each an integer from 0 to 5; R₃ and R₄ are each selected

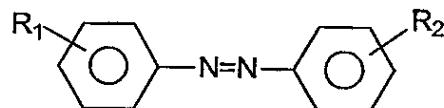
from a single, multiple, or fused ring C₆ to C₂₄ aromatic group; and M includes an azo group or a metal component. R₃ and R₄ are each preferably selected from a C₆ to C₁₀ aromatic group, more preferably selected from phenyl, benzyl, naphthyl, benzamido, and benzothiazyl. R₁ and R₂ are each preferably selected from a substituted or unsubstituted C₁ to C₁₀ linear, branched, or cyclic alkyl, alkoxy, or alkylthio group or a C₆ to C₁₀ aromatic group. When R₁, R₂, R₃, or R₄, are substituted, the substitution may include one or more of the following substituent groups: hydroxy and metal salts thereof; mercapto and metal salts thereof; halogen; amino, nitro, cyano, and amido; carboxyl including esters, acids, and metal salts thereof; silyl; acrylates and metal salts thereof; sulfonyl or sulfonamide; and phosphates and phosphites. When M is a metal component, it may be any suitable elemental metal available to those of ordinary skill in the art. Typically, the metal will be a transition metal, although preferably it is tellurium or selenium. In one embodiment, the optional aromatic component has the formula:

15



20 In one preferred embodiment, the optional aromatic component for use in the cis-to-trans catalyst has the formula:

25



In the first of these two structures, selenium may be used in place of the tellurium if desired. In a most preferred embodiment, R₃ and R₄ are each a C₆ aryl group and M includes an azo group.

30 The cis-to-trans catalyst can also include a Group VIA component, as defined herein. Elemental sulfur and polymeric sulfur are commercially available from, e.g., Elastochem, Inc. of Chardon, OH. Exemplary sulfur catalyst compounds include PB(RM-S)-80 elemental sulfur and PB(CRST)-65 polymeric sulfur, each of which is available from Elastochem, Inc. An exemplary tellurium catalyst under the tradename TELLOY and an exemplary selenium catalyst under the tradename VANDEX are each commercially available from RT Vanderbilt.

It is to be understood that when elemental sulfur or polymeric sulfur is included in the *cis*-to-*trans* catalyst, an accelerator may be used to improve the performance of the *cis*-to-*trans* catalyst and increase the *trans*- conversion for a given amount of sulfur catalyst. Suitable accelerators include, but are not limited to, sulfenamide, such as N-
5 oxydiethylene 2-benzothiazole-sulfenamide, thiazole, such as benzothiazyl disulfide, dithiocarbamate, such as bismuth dimethyldithiocarbamate, thiuram, such as tetrabenzyl thiuram disulfide, xanthate, such as zinc isopropyl xanthate, thiadiazine, thiourea, such as trimethylthiourea, guanadine, such as N,N'-di-ortho-tolylguanadine, or aldehyde-amine, such as a butyraldehyde-aniline condensation product, or mixtures thereof.
10 The *cis*-to-*trans* catalyst is preferably present in an amount from about 0.1 to 25 parts per hundred of the total resilient polymer component. More preferably, the *cis*-to-*trans* catalyst is present in an amount from about 0.1 to 12 parts per hundred of the total resilient polymer component. Most preferably, the *cis*-to-*trans* catalyst is present in an amount from about 0.1 to 8 parts per hundred of the total resilient polymer component. The
15 *cis*-to-*trans* catalyst is typically present in an amount sufficient to produce the reaction product so as to increase the *trans*- polybutadiene isomer content to contain from about 5 percent to 70 percent *trans*-polybutadiene based on the total resilient polymer component.

The measurement of *trans*- isomer content of polybutadiene referred to herein was and can be accomplished as follows. Calibration standards are prepared using at least two polybutadiene rubber samples of known *trans*- content, *e.g.*, high and low percent *trans*-polybutadiene). These samples are used alone and blended together in such a way as to create a ladder of *trans*-polybutadiene content of at least about 1.5 % to 50% or to bracket the unknown amount, such that the resulting calibration curve contains at least about 13 equally spaced points.

25 Using a commercially available Fourier Transform - Infrared (FT-IR) spectrometer equipped with a Photoacoustic (PAS) cell, a PAS spectrum of each standard was obtained using the following instrument parameters: scan at speed of 2.5 KHz (0.16 cm/sec optical velocity), use a 1.2 KHz electronic filter, set an undersampling ratio of 2 (number of laser signal zero crossings before collecting a sample), co-add a minimum of 30 128 scans at a resolution of 4 cm⁻¹ over a range of 375 to 4000 cm⁻¹ with a sensitivity setting of 1.

The *cis*-, *trans*-, and vinyl-polybutadiene peaks found between 600 and 1100cm⁻¹ from the PAS spectra can be integrated. The area under the *trans*-polybutadiene peaks as a fraction of the total area under the three isomer peaks can then be determined to
35 construct a calibration curve of the *trans*-polybutadiene area fraction versus the actual

trans-polybutadiene content. The correlation coefficient (R^2) of the resulting calibration curve must be a minimum of 0.95.

A PAS spectrum is obtained using the parameters described above for the unknown core material at the point of interest (e.g., the surface or center of the core) by 5 filling the PAS cell with a sample containing a freshly cut, uncontaminated surface free of foreign matters such as mold release and the like. The *trans*-polybutadiene area fraction of the unknown is analyzed to determine the actual *trans*-isomer content from the calibration curve. An increase in the *trans*- content anywhere in the article being manufactured or tested should be understood herein to refer to the *trans*- at any point in the article.

10 In one known circumstance when barium sulfate is included, the above method for testing *trans*- content may be less accurate. Thus, an additional or alternative test of the *trans*- content of polybutadiene is as follows. Calibration standards are prepared using at least two polybutadienes of known *trans*- content (e.g., high and low percent *trans*-polybutadiene). These samples are used alone and blended together in such a way as to 15 create a ladder of *trans*-polybutadiene content of at least about 1.5 % to 50% or to bracket the unknown amount, such that the resulting calibration curve contains at least about 13 equally spaced points.

Using a Fourier Transform - Raman (FT-Raman) spectrometer equipped with a near-infrared laser, a Stokes Raman spectrum should be obtained from each standard 20 using the following instrument parameters: sufficient laser power to obtain a good signal to noise ratio without causing excessive heating or fluorescence (typically about 400 to 800 mW is suitable); a resolution of 2 cm^{-1} ; over a Raman shift spectral range of about 400 to 4000 cm^{-1} ; and co-adding at least 300 scans.

A calibration curve may be constructed from the data generated above, using 25 a chemometrics approach and software such as PLSplus/IQ from Galactic Industries Corp. of Salem, NH. An acceptable calibration was obtained with this software using a PLS-1 curve generated using an SNV (detrend) pathlength correction, a mean center data preparation, and a 5-point SG second derivative over the spectral range from about 1600 to 1700 cm^{-1} . The correlation coefficient (R^2) of the resulting calibration curve must be a 30 minimum of 0.95.

A Raman spectrum of the unknown core material is obtained using this instrument at the point of interest in the unknown sample (e.g., surface or center of the golf ball core). The unknown must be free of foreign matter, such as mold release, etc. Analyze the spectrum of the unknown using the PLS calibration curve to determine *trans*-35 polybutadiene isomer content of the unknown sample.

A free-radical source, often alternatively referred to as a free-radical initiator, is required in the composition and method. The free-radical source is typically a peroxide, and preferably an organic peroxide. Suitable free-radical sources include di-t-amyl peroxide, di(2-t-butyl-peroxyisopropyl)benzene peroxide, 1,1-bis(t-butylperoxy)-3,3,5-5 trimethylcyclohexane, dicumyl peroxide, di-t-butyl peroxide, 2,5-di-(t-butylperoxy)-2,5-dimethyl hexane, n-butyl-4,4-bis(t-butylperoxy)valerate, lauryl peroxide, benzoyl peroxide, t-butyl hydroperoxide, and the like, and any mixture thereof. The peroxide is typically present in an amount greater than about 0.1 parts per hundred of the total resilient polymer component, preferably about 0.1 to 15 parts per hundred of the resilient polymer 10 component, and more preferably about 0.2 to 5 parts per hundred of the total resilient polymer component. It should be understood by those of ordinary skill in the art that the presence of certain cis-to-trans catalysts according to the invention may require a larger amount of free-radical source, such as the amounts described herein, compared to conventional cross-linking reactions. The free radical source may alternatively or 15 additionally be one or more of an electron beam, UV or gamma radiation, x-rays, or any other high energy radiation source capable of generating free radicals. It should be further understood that heat often facilitates initiation of the generation of free radicals.

Crosslinkers are included to increase the hardness of the reaction product. Suitable crosslinking agents include one or more metallic salts of unsaturated fatty acids or 20 monocarboxylic acids, such as zinc, calcium, or magnesium acrylate salts, and the like, and mixtures thereof. Preferred acrylates include zinc acrylate, zinc diacrylate, zinc methacrylate, and zinc dimethacrylate, and mixtures thereof. The crosslinking agent must be present in an amount sufficient to crosslink a portion of the chains of polymers in the resilient polymer component. For example, the desired compression may be obtained by 25 adjusting the amount of crosslinking. This may be achieved, for example, by altering the type and amount of crosslinking agent, a method well-known to those of ordinary skill in the art. The crosslinking agent is typically present in an amount greater than about 0.1 percent of the resilient polymer component, preferably from about 10 to 40 percent of the resilient polymer component, more preferably from about 10 to 30 percent of the resilient 30 polymer component. When an organosulfur is selected as the cis-to-trans catalyst, zinc diacrylate may be selected as the crosslinking agent and is present in an amount of less than about 25 phr.

Fillers added to one or more portions of the golf ball typically include processing aids or compounds to affect rheological and mixing properties, the specific 35 gravity (*i.e.*, density-modifying fillers), the modulus, the tear strength, reinforcement, and the like. The fillers are generally inorganic, and suitable fillers include numerous metals or

metal oxides, such as zinc oxide and tin oxide, as well as barium sulfate, zinc sulfate, calcium carbonate, barium carbonate, clay, tungsten, tungsten carbide, an array of silicas, and mixtures thereof. Fillers may also include various foaming agents or blowing agents which may be readily selected by one of ordinary skill in the art. Foamed polymer blends 5 may be formed by blending ceramic or glass microspheres with polymer material. Polymeric, ceramic, metal, and glass microspheres may be solid or hollow, and filled or unfilled. Fillers are typically also added to one or more portions of the golf ball to modify the density thereof to conform to uniform golf ball standards. Fillers may also be used to modify the weight of the center or at least one additional layer for specialty balls, e.g., a 10 lower weight ball is preferred for a player having a low swing speed.

The resilient polymer component may also include one or more additional polymers, such as a thermoplastic copolyesterester block copolymer, dynamically vulcanized thermoplastic elastomer, hydrogenated or non-hydrogenated styrene-butadiene elastomer with functional groups such as maleic anhydride or sulfonic acid attached, 15 thermoplastic polyurethane or polymers made using a metallocene catalyst, or blends thereof. Suitable thermoplastic copolyetheresters include HYTREL® 3078 and HYTREL® 4069, which are commercially available from E.I. DuPont de Nemours & Co. of Wilmington, DE. Suitable dynamically vulcanized thermoplastic elastomers include SANTOPRENE®, commercially available from Advanced Elastomer Systems of Akron, 20 OH. Examples of suitable functionalized styrene-butadiene elastomers, include KRATON FG-1901x and FG-1921x, which are available from the Shell Corporation of Houston, TX. Examples of suitable thermoplastic polyurethanes include ESTANE® 58133 and ESTANE® 58144, which are commercially available from the B.F. Goodrich Company of Cleveland, OH. Further, the materials for the mantle layer described above may be in the 25 form of a foamed polymeric material. For example, suitable metallocene polymers include foams of thermoplastic elastomers based on metallocene single-site catalyst-based foams. Suitable thermoplastic polyetheramides include PEBAX® 2533, PEBAX® 1205 and PEBAX® 4033 which are available from Elf-Atochem of Philadelphia, PA. Suitable thermoplastic ionomer resins include any number of olefinic based ionomers including 30 SURLYN® and IOTEK®, which are commercially available from E.I. DuPont de Nemours & Co. of Wilmington, DE, and Exxon Corporation of Irving, TX, respectively. When the resilient polymer component includes any additional polymers in addition to polybutadiene, polybutadiene will be present in at least 50 phr of the resilient polymer component, preferably in an amount greater than about 90 phr.

35 The resilient polymer component, additional polymers, free-radical initiator, filler(s), and any other materials used in forming either the golf ball center or any portion of

the core, in accordance with invention, may be combined to form a mixture by any type of mixing known to one of ordinary skill in the art. Suitable types of mixing include single pass and multi-pass mixing, and the like. The crosslinking agent, and any other optional additives used to modify the characteristics of the golf ball center or additional layer(s),

5 may similarly be combined by any type of mixing. A single-pass mixing process where ingredients are added sequentially is preferred, as this type of mixing tends to increase efficiency and reduce costs for the process. The preferred mixing cycle is single step wherein the polymer, cis-trans catalyst, filler, zinc diacrylate, and peroxide are added sequentially. Suitable mixing equipment is well known to those of ordinary skill in the art,

10 and such equipment may include a Banbury mixer, a two-roll mill, or a twin screw extruder. Conventional mixing speeds for combining polymers are typically used, although the speed must be high enough to impart substantially uniform dispersion of the constituents. On the other hand, the speed should not be too high, as high mixing speeds tend to break down the polymers being mixed and particularly may undesirably decrease the molecular weight of

15 the resilient polymer component. The speed should thus be low enough to avoid high shear, which may result in loss of desirably high molecular weight portions of the polymer component. Also, too high a mixing speed may undesirably result in creation of enough heat to initiate the crosslinking before the preforms are shaped and assembled around a core. The mixing temperature depends upon the type of polymer components, and more

20 importantly, on the type of free-radical initiator. For example, when using di(2-t-butyl-peroxyisopropyl)benzene as the free-radical initiator, a mixing temperature of about 80°C to 125°C, preferably about 88°C to 110°C, and more preferably about 90°C to 100°C, is suitable to safely mix the ingredients. Additionally, it is important to maintain a mixing temperature below the peroxide decomposition temperature. For example, if dicumyl

25 peroxide is selected as the peroxide, the temperature should not exceed 200°F. Suitable mixing speeds and temperatures are well-known to those of ordinary skill in the art, or may be readily determined without undue experimentation.

The mixture can be subjected to, *e.g.*, a compression or injection molding process, to obtain solid spheres for the center or hemispherical shells for forming an

30 intermediate layer. The polymer mixture is subjected to a molding cycle in which heat and pressure are applied while the mixture is confined within a mold. The cavity shape depends on the portion of the golf ball being formed. The compression and heat liberates free radicals by decomposing one or more peroxides, which may initiate the cis-to-trans conversion and crosslinking simultaneously. The temperature and duration of the molding

35 cycle are selected based upon the type of peroxide and cis-trans catalyst selected. The molding cycle may have a single step of molding the mixture at a single temperature for a

fixed time duration. An example of a single step molding cycle, for a mixture that contains dicumyl peroxide, would hold the polymer mixture at 340°F for a duration of 15 minutes. The molding cycle may also include a two-step process, in which the polymer mixture is held in the mold at an initial temperature for an initial duration of time, followed by holding 5 at a second, typically higher temperature for a second duration of time. An example of a two-step molding cycle would be holding the mold at 290°F for 40 minutes, then ramping the mold to 340°F where it is held for a duration of 20 minutes. In a preferred embodiment of the current invention, a single-step cure cycle is employed. Single-step processes are effective and efficient, reducing the time and cost of a two-step process. The resilient 10 polymer component, polybutadiene, cis-to-trans conversion catalyst, additional polymers, free-radical initiator, filler, and any other materials used in forming either the golf ball center or any portion of the core, in accordance with the invention, may be combined to form a golf ball by an injection molding process, which is also well-known to one of ordinary skill in the art. Although the curing time depends on the various materials 15 selected, a particularly suitable curing time is about 5 to 18 minutes, preferably from about 8 to 15 minutes, and more preferably from about 10 to 12 minutes. Those of ordinary skill in the art will be readily able to adjust the curing time upward or downward based on the particular materials used and the discussion herein.

The cured resilient polymer component, which contains a greater amount of 20 trans-polybutadiene than the uncured resilient polymer component, is formed into an article having a first hardness at a point in the interior and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness. Preferably, the article is a sphere and the point is the midpoint of the article. In another embodiment, the second hardness differs from the first by greater than 20 percent of 25 the first hardness. The cured article also has a first amount of *trans*-polybutadiene at an interior location and a second amount of *trans*-polybutadiene at a surface location, wherein the first amount is at least about 6 percent less than the second amount, preferably at least about 10 percent less than the second amount, and more preferably at least about 20 percent less than the second amount. The interior location is preferably a midpoint and the article is 30 preferably a sphere.

The compression of the core, or portion of the core, of golf balls prepared according to the invention is preferably below about 50, more preferably below about 25.

The cover provides the interface between the ball and a club. Properties that are desirable for the cover are good moldability, high abrasion resistance, high tear strength, 35 high resilience, and good mold release, among others. The cover typically has a thickness to provide sufficient strength, good performance characteristics and durability. The cover

of the golf balls typically has a thickness of at least about 0.03 inches, preferably 0.03 to 0.125 inches, and more preferably from about 0.05 to 0.1 inches. The golf balls also typically have at least about 60 percent dimple coverage, preferably at least about 70 percent dimple coverage, of the surface area of the cover.

5 The cover can include any suitable cover or intermediate layer materials, known to those of ordinary skill in the art, including thermoplastic and thermosetting materials, but preferably the cover or intermediate layer can include any suitable materials, such as ionic copolymers of ethylene and an unsaturated monocarboxylic acid which are available under the trademark SURLYN of E.I. DuPont de Nemours & Co., of Wilmington, 10 DE, or IOTEK or ESCOR of Exxon. These are copolymers or terpolymers of ethylene and methacrylic acid or acrylic acid partially neutralized with salts of zinc, sodium, lithium, magnesium, potassium, calcium, manganese, nickel or the like, in which the salts are the reaction product of an olefin having from 2 to 8 carbon atoms and an unsaturated 15 monocarboxylic acid having 3 to 8 carbon atoms. The carboxylic acid groups of the copolymer may be totally or partially neutralized and might include methacrylic, crotonic, maleic, fumaric or itaconic acid.

This golf ball can likewise include one or more homopolymeric or copolymeric cover materials, such as:

- (1) Vinyl resins, such as those formed by the polymerization of vinyl chloride, 20 or by the copolymerization of vinyl chloride with vinyl acetate, acrylic esters or vinylidene chloride;
- (2) Polyolefins, such as polyethylene, polypropylene, polybutylene and copolymers such as ethylene methylacrylate, ethylene ethylacrylate, ethylene vinyl acetate, ethylene methacrylic or ethylene acrylic acid or propylene 25 acrylic acid and copolymers and homopolymers produced using a single-site catalyst;
- (3) Polyurethanes, such as those prepared from polyols and diisocyanates or polyisocyanates and those disclosed in U. S. Patent No. 5,334,673;
- (4) Polyureas, such as those disclosed in U.S. Patent No. 5,484,870;
- (5) Polyamides, such as poly(hexamethylene adipamide) and others prepared 30 from diamines and dibasic acids, as well as those from amino acids such as poly(caprolactam), and blends of polyamides with SURLYN, polyethylene, ethylene copolymers, ethyl-propylene-non-conjugated diene terpolymer, and the like;
- (6) Acrylic resins and blends of these resins with poly vinyl chloride, 35 elastomers, and the like;

(7) Thermoplastics, such as urethanes; olefinic thermoplastic rubbers, such as blends of polyolefins with ethylene-propylene-non-conjugated diene terpolymer; block copolymers of styrene and butadiene, isoprene or ethylene-butylene rubber; or copoly(ether-amide), such as PEBAX, sold by ELF Atochem of Philadelphia, PA;

5 (8) Polyphenylene oxide resins or blends of polyphenylene oxide with high impact polystyrene as sold under the trademark NORYL by General Electric Company of Pittsfield, MA;

10 (9) Thermoplastic polyesters, such as polyethylene terephthalate, polybutylene terephthalate, polyethylene terephthalate/glycol modified and elastomers sold under the trademarks HYTREL by E.I. DuPont de Nemours & Co. of Wilmington, DE, and LOMOD by General Electric Company of Pittsfield, MA;

15 (10) Blends and alloys, including polycarbonate with acrylonitrile butadiene styrene, polybutylene terephthalate, polyethylene terephthalate, styrene maleic anhydride, polyethylene, elastomers, and the like, and polyvinyl chloride with acrylonitrile butadiene styrene or ethylene vinyl acetate or other elastomers; and

20 (11) Blends of thermoplastic rubbers with polyethylene, propylene, polyacetal, nylon, polyesters, cellulose esters, and the like.

Preferably, the cover includes polymers, such as ethylene, propylene, butene-1 or hexane-1 based homopolymers or copolymers including functional monomers, such as acrylic and methacrylic acid and fully or partially neutralized ionomer resins and their blends, methyl acrylate, methyl methacrylate homopolymers and copolymers, imidized, amino group containing polymers, polycarbonate, reinforced polyamides, polyphenylene oxide, high impact polystyrene, polyether ketone, polysulfone, poly(phenylene sulfide), acrylonitrile-butadiene, acrylic-styrene-acrylonitrile, poly(ethylene terephthalate), poly(butylene terephthalate), poly(ethylene vinyl alcohol), poly(tetrafluoroethylene) and their copolymers including functional comonomers, and blends thereof. Suitable cover compositions also include a polyether or polyester thermoplastic urethane, a thermoset polyurethane, a low modulus ionomer, such as acid-containing ethylene copolymer ionomers, including E/X/Y terpolymers where E is ethylene, X is an acrylate or methacrylate-based softening comonomer present in about 0 to 50 weight percent and Y is acrylic or methacrylic acid present in about 5 to 35 weight percent. More preferably, in a low spin rate embodiment designed for maximum distance, the acrylic or methacrylic acid

is present in about 15 to 35 weight percent, making the ionomer a high modulus ionomer. In a high spin embodiment, the cover includes an ionomer where an acid is present in about 10 to 15 weight percent and includes a softening comonomer.

The cover may also be formed from the present invention, as discussed
5 herein.

Depending on the desired properties, balls prepared according to the invention can exhibit substantially the same or higher resilience, or coefficient of restitution (CoR), with a decrease in compression or modulus, compared to balls of conventional construction. Additionally, balls prepared according to the invention can also exhibit
10 substantially higher resilience, or coefficient of restitution (CoR), without an increase in compression, compared to balls of conventional construction. Another measure of this resilience is the "loss tangent," or $\tan \delta$, which is obtained when measuring the dynamic stiffness of an object. Loss tangent and terminology relating to such dynamic properties is typically described according to ASTM D4092-90. Thus, a lower loss tangent indicates a
15 higher resiliency, thereby indicating a higher rebound capacity. Low loss tangent indicates that most of the energy imparted to a golf ball from the club is converted to dynamic energy, *i.e.*, launch velocity and resulting longer distance. The rigidity or compressive stiffness of a golf ball may be measured, for example, by the dynamic stiffness. A higher dynamic stiffness indicates a higher compressive stiffness. To produce golf balls having a
20 desirable compressive stiffness, the dynamic stiffness of the crosslinked reaction product material should be less than about 50,000 N/m at -50°C. Preferably, the dynamic stiffness should be between about 10,000 and 40,000 N/m at -50°C, more preferably, the dynamic stiffness should be between about 20,000 and 30,000 N/m at -50°C.

The dynamic stiffness is similar in some ways to dynamic modulus.
25 Dynamic stiffness is dependent on probe geometry as described herein, whereas dynamic modulus is a unique material property, independent of geometry. The dynamic stiffness measurement has the unique attribute of enabling quantitative measurement of dynamic modulus and exact measurement of loss tangent at discrete points within a sample article. In the case of this invention, the article is a golf ball core. The polybutadiene reaction
30 product preferably has a loss tangent below about 0.1 at -50°C, and more preferably below about 0.07 at -50°C.

The resultant golf balls typically have a coefficient of restitution of greater than about 0.7, preferably greater than about 0.75, and more preferably greater than about 0.78. The golf balls also typically have an Atti compression (which has been referred to as
35 PGA compression in the past) of at least about 40, preferably from about 50 to 120, and more preferably from about 60 to 100. Compression values are dependent on the diameter

of the article being measured. The golf ball polybutadiene material of the present invention typically has a flexural modulus of from about 500 psi to 300,000 psi, preferably from about 2000 to 200,000 psi. The golf ball polybutadiene material typically has a hardness of at least about 15 Shore A, preferably between about 30 Shore A and 80 Shore D, more 5 preferably between about 50 Shore A and 60 Shore D. The specific gravity is typically greater than about 0.7, preferably greater than about 1, for the golf ball polybutadiene material. The dynamic shear storage modulus, or storage modulus, of the golf ball polybutadiene material at about 23°C is typically at least about 10,000 dyn/cm², preferably from about 10⁴-10¹⁰ dyn/cm², more preferably from about 10⁶ to 10¹⁰ dyn/cm².

10 The molding process and composition of golf ball portions typically results in a gradient of material properties. Methods employed in the prior art generally exploit hardness to quantify these gradients. Hardness is a qualitative measure of static modulus and does not represent the modulus of the material at the deformation rates associated with golf ball use, *i.e.*, impact by a club. As is well known to one skilled in the art of polymer 15 science, the time-temperature superposition principle may be used to emulate alternative deformation rates. For golf ball portions including polybutadiene, a 1-Hz oscillation at temperatures between 0°C and -50°C are believed to be qualitatively equivalent to golf ball impact rates. Therefore, measurement of loss tangent and dynamic stiffness at 0°C to -50°C may be used to accurately anticipate golf ball performance, preferably at 20 temperatures between about -20°C and -50°C.

Additionally, the unvulcanized rubber, such as polybutadiene, in golf balls prepared according to the invention typically has a Mooney viscosity greater than about 20, preferably greater than about 30, and more preferably greater than about 40. Mooney viscosity is typically measured according to ASTM D-1646.

25 When golf balls are prepared according to the invention, they typically will have dimple coverage greater than about 60 percent, preferably greater than about 65 percent, and more preferably greater than about 70 percent. The flexural modulus of the cover on the golf balls, as measured by ASTM method D-790, is typically greater than about 500 psi, and is preferably from about 500 psi to 150,000 psi. The hardness of the 30 cover is typically from about 35 to 80 Shore D, preferably from about 40 to 78 Shore D, and more preferably from about 45 to 75 Shore D.

Referring to Figure 1, a golf ball 10 of the present invention can include a core 12 and a cover 16 surrounding the core 12. Referring to Figure 2, a golf ball 20 of the present invention can include a center 22, a cover 26, and at least one intermediate layer 24 35 disposed between the cover and the center. Each of the cover and center may also include more than one layer; *i.e.*, the golf ball can be a conventional three-piece wound ball, a two-

piece ball, a ball having a multi-layer core or an intermediate layer or layers, etc. Thus, referring to Figure 3, a golf ball 30 of the present invention can include a center 32, a cover 38, and intermediate layers 34 and 36 disposed between the cover and the center. Although Figure 3 shows only two intermediate layers, it will be appreciated that any number or type 5 of intermediate layers may be used, as desired.

EXAMPLES

A variety of metal sulfide *cis*-to-*trans* catalysts that successfully converted a portion of the *cis*-polybutadiene isomer to the *trans*- isomer are presented in Table 1.

10 CARIFLEX BR-1220 polybutadiene (100 phr) was reacted with zinc oxide (5 phr), dicumyl peroxide (3 phr, the free radical initiator), and zinc diacrylate (25 phr), to form the reaction product as described in the present invention.

Trans- isomer conversion percentages range from below 6 percent to above 16 percent for the various catalysts that are present in amounts ranging from below 2 phr to 15 above 5 phr. The table clearly demonstrates the effectiveness of numerous different *cis*-to-*trans* catalysts, at varying concentrations, for increasing the *trans*-polybutadiene content.

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TABLE 1: Metal Sulfide Conversion Examples

	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Polybutadiene (CARIFLEX 1220)															
Zinc Oxide	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Dicumyl peroxide	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Zinc Diacrylate	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Cis-Trans "Catalyst"															
FeS	2.87														
MnS	2.65														
TiS ₂		1.70													
CaS			2.20												
CoS				2.77											
MoS ₂					2.43										
WS ₂						3.77									
Cu ₂ S							4.65								
SeS ₂								2.19							
Y ₂ S ₃									2.76						
ZnS										2.97					
Sb ₂ S ₃											3.45				
Bi ₂ S ₃												5.22			
% Trans BR isomer Precure	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
% Trans BR isomer Postcure	10.5	16.1	17.0	8.3	10.3	10.1	9.2	5.8	5.2	10.2	10.1	10.7	10.5		

EXAMPLE 1: A Core Prepared From According to the Invention, Employing an Organosulfur Cis-to-trans Catalyst.

5 A core according to the present invention was created employing an organosulfur compound as the cis-to-trans conversion catalyst. The resultant core properties clearly demonstrate the advantages of a golf ball core made according to the current invention as compared to example cores constructed with conventional technology. The components and physical characteristics are presented in Table 2.

10 The compressive load of cores prepared according to the invention is approximately half of the compressive load of cores constructed in accordance with U.S. Patent No. 5,697,856, U.S. Patent No. 5,252,652, and U.S. Patent No. 4,692,497, while at the same time retaining roughly the same, and in some cases higher, CoR (resilience). The core made according to the current invention has a lower compressive load (soft), yet is
15 resilient (fast). The compressive load is greater than that of a core constructed in accordance with U.S. Patent No. 3,239,228, but has a significantly higher CoR. The core of U.S. Patent No. 3,239,228 is very soft and very slow (very low CoR).

20 The percent change in dynamic stiffness from 0°C to -50°C was also measured at both the edge and center of the cores. The dynamic stiffness at both the edge
25 and the center of the core of the current invention varied only slightly, less than 20 percent, over the temperature range investigated. The core made according to U.S. Patent No. 3,239,228 varied over 230 percent, whereas the cores made according to other conventional technology, had a dynamic stiffness that varied by greater than 130 percent, and typically by as much as 150 percent, over the same temperature range.

30 The percent of *trans*- conversion was also measured at both the center and edge of the core prepared according to the current invention, and for cores prepared as disclosed in the same four patents mentioned above, allowing a *trans*- gradient to be calculated. The core according to the current invention had a *trans*- gradient of about 32 percent from edge to center. For the core prepared according to the current invention, the
35 pre- and post-cure *trans*- percentages was also measured to determine the effectiveness of that process. The percentage of polybutadiene converted to the *trans*- isomer ranged from almost 40 percent at the center to greater than 55 percent at the edge. Two of the cores prepared according to conventional technology, U.S. Patent No. 3,239,228 and U.S. Patent No. 4,692,497, had a zero *trans*- gradient. A third core, prepared according to U.S. Patent No. 5,697,856, had only a slight *trans*- gradient, less than 18 percent from edge to center. A

fourth core, prepared according to U.S. Patent No. 5,252,652, had a very large gradient, almost 65 percent from edge to center.

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EXAMPLE 2: A Core Prepared From According to the Invention, Employing an Inorganic Sulfide Cis-to-trans Catalyst.

A core according to the present invention was created employing an inorganic sulfide compound as the cis-to-trans conversion catalyst. The resultant core 10 properties clearly demonstrate the advantages of a golf ball core made according to the current invention as compared to example cores constructed with conventional technology. The components and physical characteristics are presented in Table 2.

The compressive load is approximately half of the compressive load of three cores constructed in accordance with U.S. Patent No. 5,697,856, U.S. Patent No. 5,252,652, 15 and U.S. Patent No. 4,692,497, while at the same time retaining roughly the same, and in some cases, a higher CoR (resilience). The core made according to the current invention is soft, yet resilient (fast). The compressive load is greater than a core constructed in accordance with U.S. Patent No. 3,239,228, but has a significantly higher CoR. The core of U.S. Patent No. 3,239,228 is very soft and very slow (low CoR).

20 The percent change in dynamic stiffness from 0°C to -50°C was also measured at both the edge and center of the cores. The dynamic stiffness at both the edge and the center of the core of the current invention varied only slightly, less than 125 percent, over the temperature range investigated. The core made according to U.S. Patent No. 3,239,228 varied over 230 percent, whereas the cores made according to other conventional 25 technology, had a dynamic stiffness that varied by greater than 130 percent, and typically by as much as 150 percent, over the same temperature range.

The percent of *trans*- conversion was also measured at both the center and edge of the core prepared according to the current invention, and for cores prepared according to the same four patents mentioned above, allowing a *trans*- gradient to be 30 calculated. The core according to the current invention had a *trans*- gradient of about 45 percent from edge to center. Two of the cores prepared in accordance with U.S. Patent No. 3,239,228 and U.S. Patent No. 4,692,497 had a zero *trans*- gradient. A third core, prepared in accordance with U.S. Patent No. 5,697,856, had only a slight *trans*- gradient, less than 18 percent from edge to center. A fourth core, prepared in accordance with U.S. Patent No. 35 5,252,652, had a very large gradient, almost 65 percent, from edge to center.

EXAMPLE 3: A Core Prepared From According to the Invention, Employing a Blend of Organosulfur and Inorganic Sulfide Cis-to-trans Catalyst.

5 A core according to the present invention was created employing a blend of organosulfur and inorganic sulfide compounds as the cis-to-trans conversion catalyst. The resultant core properties clearly demonstrate the advantages of a golf ball core made according to the current invention as compared to example cores constructed with conventional technology. The components and physical characteristics are presented in
10 Table 2.

The compressive load is approximately half of the compressive load of three cores constructed in accordance with U.S. Patent No. 5,697,856, U.S. Patent No. 5,252,652, and U.S. Patent No. 4,692,497, while at the same time retaining roughly the same, and in some cases a higher CoR (resilience). The core made according to the current invention is
15 soft, yet resilient (fast). The compressive load of the invention is greater than a fourth core constructed in accordance with U.S. Patent No. 3,239,228, but has a significantly higher CoR. The core constructed in accordance with U.S. Patent No. 3,239,228 is very soft and very slow (low CoR).

20 The percent change in dynamic stiffness from 0°C to -50°C was also measured at both the edge and center of the cores. The dynamic stiffness at both the edge and the center of the core of the current invention varied only slightly, less than 121 percent, over the temperature range investigated. The core made in accordance with U.S. Patent No. 3,239,228 varied over 230 percent, whereas the cores made according to other conventional technology had a dynamic stiffness that varied by greater than 130 percent, and typically by
25 as much as 150 percent, over the same temperature range.

The percent of *trans*- conversion was also measured at both the center and edge of the core prepared according to the current invention, and for cores prepared to the same four patents mentioned above, allowing a *trans*- gradient to be calculated. The core according to the current invention had a *trans*- gradient that about 44 percent from edge to
30 center. For the core prepared according to the current invention, the pre- and post-cure *trans*- percentages was also measured to determine the effectiveness of that process. The percentage of polybutadiene converted to the *trans*- isomer ranged from almost 26 percent at the center to greater than 45 percent at the edge. Two of the cores prepared in accordance with U.S. Patent No. 3,239,228 and U.S. Patent No. 4,692,497 had a zero *trans*- gradient. A
35 third core prepared in accordance with U.S. Patent No. 5,697,856 had only a slight *trans*- gradient, less than 18 percent from edge to center. A fourth core, prepared in accordance

with U.S. Patent No. 5,252,652 had a very large gradient, almost 65 percent from edge to center.

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Table 2

	Invention	Examples		Examples of Conventional Golf Balls		
		#1	#2	#3	US#3239228	
Chemical Constituents					US#5816944	US#522052
Polybutadiene (Shell, CARIFLEX 1220)	100	100	100	100	US#5697858	US#4971329
Polybutadiene (Finastra, 35 NF)					N/A	US#4632497
DMDS					N/A	N/A
Carbon Black (RA)					N/A	N/A
Wood Flour					N/A	N/A
Sulfur					N/A	N/A
Stearic Acid					N/A	N/A
Reogen					N/A	N/A
Vanok-MBPC					N/A	N/A
Triethanolamine					N/A	N/A
Zinc Oxide	5	5	5	5	24	N/A
Dicumyl Peroxide	3	1.9	2	5	1.5	N/A
Zinc Diacrylate	25	25	25	25	15	N/A
Cis-Trans "Catalyst"					2	N/A
MnS		0.82			4	N/A
Dithiobisulfide		2.5	1.5		N/A	N/A
Cu ₃ S			1		N/A	N/A
Resultant Core Properties					N/A	N/A
Load (lb) @ 0.8% Deflection 1.580" core	165.5	191.4	181.8	61.1	325	390
Coefficient of Restitution @ 125 ft/s	0.783	0.777	0.785	0.599	0.779	0.805
Hardness Shore C						480
Surface	61	76	62	35	75	80
Center	52	62	59	39	70	61
Dynamic Stiffness @ 0°C (N/m)						60.5
Edge*	253.98	278.76	264.93	831.12	627.67	830.32
Center	207.83	173.80	275.79	836.1	610.71	722.35
Dynamic Stiffness @ -50°C (N/m)						506.12
Edge*	302.95	345.23	344.55	1959.4	927.63	1090.53
Center	230.22	209.03	321.95	1861.7	898.77	1082.42
Dynamic Stiffness Ratio at -50°C/0°C						83.153
Edge*	118%	125%	121%	233%	148%	131%
Center	111%	118%	117%	223%	147%	110%
Loss Tangent 0°C						164%
Edge*	0.024	0.027	0.024	0.074	0.039	0.037
Center	0.025	0.025	0.028	0.073	0.033	0.026
Loss Tangent -50°C						0.043
Edge*	0.098	0.084	0.097	0.183	0.142	0.119
Center	0.087	0.071	0.055	0.160	0.129	0.059
% Trans BR isomer, Precure	1.5	1.5	1.5	50	N/A	N/A
% Trans BR isomer, Postcure						
Surface	55.8	6.4	45.5	50	30.2	24.6
Center	37.8	4.6	25.5	50	24.7	8.5
% Trans Variation (Surf. - Center) Surf.	32%	45%	44%	0%	18%	65%

*Edge is measured approximately 5 mm from the exterior surface of the measured article.

Example 4: Dual Core		Conventional		Example		Example		Example		Example		Example 5: Double Cover		Conventional		Example		
Center 1.15" Diameter																		
Shell 1220	100	100	Shell 1220	100	100	Shell 1220	100	100	Shell 1220	100	100	Shell 1220	100	100	Shell 1220	100	100	
ZDA	20	20	ZDA	24	24	ZDA	24	24	ZDA	26	26	ZDA	26	26	ZDA	26	26	
Varox 802-40KE-HP	0.89	0	Varox 231 XL	0.42	0	Varox 231 XL	0.42	0	Varox 231 XL	0.42	0	Varox 231 XL	0.42	0	Varox 231 XL	0.42	0	
Dicumyl Peroxide	0	2.5	DBDB-60	0.15	0	DBDB-60	0.15	0	DBDB-60	0.15	0	DBDB-60	0.15	0	DBDB-60	0.15	0	
Zinc Oxide	40	39	Dicumyl Peroxide	0	3	Zinc Oxide	21	20	Dicumyl Peroxide	0	3	Zinc Oxide	20	18	Dicumyl Peroxide	0	3	
DTDS	0	0.75	Zinc Oxide	21	20	Zinc Oxide	20	18	Zinc Oxide	20	18	Zinc Oxide	20	18	Zinc Oxide	20	18	
% Trans			DTDS	0	2.5	DTDS	0	2.5	DTDS	0	2.5	DTDS	0	2.5	DTDS	0	2.5	
Precure	1.5	1.5	% Trans			% Trans			% Trans			% Trans			% Trans			
Postcure	1.5	40	Precure			Precure			Precure			Precure			Precure			
Load in lbs Required	85	109	Postcure			Postcure			Postcure			Postcure			Postcure			
10.8% Deflection			Alt Comp			Alt Comp			Alt Comp			Alt Comp			Alt Comp			
Manhole 1.58" Diameter		Inner Cover 1.51" Diameter		Cover Material		Cover Material		Cover Material		Cover Material		Cover Material		Cover Material		Cover Material		
Shell 1220	80	80	Hytreel	60	60	Na VLM	30	30	Na VLM	30	30	Na VLM	30	30	Na VLM	30	30	
ZDA	38	38	Nucrel	20	20	Na SURLYN	30	30	Na SURLYN	30	30	Na SURLYN	30	30	Na SURLYN	30	30	
Varox 231 XL	0.42	0.42	Zinc Oxide	20	20	Li SURLYN	40	40	Li SURLYN	40	40	Li SURLYN	40	40	Li SURLYN	40	40	
DBBB-60	0.15	0.15	Shore D	29	29	Shore D	63	63	Shore D	63	63	Shore D	63	63	Shore D	63	63	
Zinc Oxide	6	6	Cover Material			Cover Material			Cover Material			Cover Material			Cover Material			
Polysoprene	20	20	Na SURLYN	30	30	Compression	91	48	Compression	91	48	Compression	91	48	Compression	91	48	
Dual Core Properties 1.58" Diameter	78	77	Li SURLYN	40	40	CoR	0.791	0.791	CoR	0.791	0.791	CoR	0.791	0.791	CoR	0.791	0.791	
Compression	0.774	0.789	Shore D	71	71	Driver Spin	3300	2900	Driver Spin	3300	2900	Driver Spin	3300	2900	Driver Spin	3300	2900	
Cover Material			Ball Properties			Ball Properties			Ball Properties			Ball Properties			Ball Properties			
Na VLM	30	30	Compression	89	70	Compression	89	70	Compression	89	70	Compression	89	70	Compression	89	70	
Na SURLYN	30	30	CoR	0.793	0.793	CoR	0.793	0.793	CoR	0.793	0.793	CoR	0.793	0.793	CoR	0.793	0.793	
Li SURLYN	40	40	Driver Spin	N/A	N/A	Driver Spin	N/A	N/A	Driver Spin	N/A	N/A	Driver Spin	N/A	N/A	Driver Spin	N/A	N/A	
Shore D	63	63																
Ball Properties																		
Compression	89	69																
CoR	0.791	0.802																
Driver Spin	2800	2850																

TABLE 3

EXAMPLE 4: Comparison of a Conventional Dual Core Ball to Dual Core Ball Prepared According to the Invention.

A dual core golf ball according to the present invention was created having a solid center, an intermediate layer surrounding the solid center, and a cover disposed concentrically around the intermediate layer. The components and physical characteristics are presented in Table 3.

5

A solid center was constructed for the ball of the present invention and for a ball of conventional technology. The centers were both created from CARIFLEX BR1220 polybutadiene as the starting material, the only difference being replacing the VAROX 802-40KE-HP peroxide (conventional technology) with a DTDS cis-to-trans catalyst of the current invention and dicumyl peroxide. This substitution allows a portion of the 10 polybutadiene material to be converted to the *trans*- configuration during the molding process. The resulting solid centers had outside diameters of approximately 1.15 inches. The polybutadiene reaction product prepared thereby had a *trans*- isomer content of 40 percent compared to the 1.5 percent *trans*- isomer of the conventional ball. Identical 15 intermediate layers, having outside diameters of approximately 1.58 inches, were constructed around each solid center to form a core.

The compression and CoR values were measured for the two cores. The compression of the core prepared according to the current invention was measured to be 77 and the compression of the core of the conventional ball was measured to be 78. The CoR value of the conventional center was measured to be 0.774, whereas the CoR value of the 20 core of the present invention was measured to be 0.789. Therefore, the present invention resulted in a center and a core having a higher resilience at similar compression compared to a center constructed with conventional technology.

An identical cover was added to both centers and the compression and CoR 25 were measured again. The compression for both balls was measured to be 89, yet the CoR values were 0.791 and 0.802 for the conventional ball and the ball of the present invention, respectively. The present invention resulted in a ball having the same compression with a higher resilience (CoR) compared to a ball constructed with conventional technology.

EXAMPLE 5: Comparison of a Conventional Double Cover Ball to Double Cover Ball Prepared According to the Invention.

A double cover golf ball according to the present invention was created having a solid center, an inner cover surrounding the solid center, and a cover disposed concentrically around the inner cover. The components and physical characteristics are 30 presented in Table 3.

35

A solid center was constructed for the ball of the present invention and for a ball of conventional technology. The centers were both created from a CARIFLEX

BR1220 polybutadiene starting material, the only difference being the replacing of a pair of peroxides, VAROX 231 XL and DBDB-60 (conventional technology), with a DTDS cis-to-trans catalyst of the current invention and dicumyl peroxide to facilitate cis-to-trans conversion. The resulting solid centers had outside diameters of approximately 1.39 inches. The polybutadiene reaction product of the current invention had a *trans*- isomer content of 5 55 percent compared to the 1.5 percent *trans*- isomer of the conventional center. Identical inner covers, having outside diameters of approximately 1.51 inches, were constructed around the solid center.

An identical cover was added to both centers and the compression and CoR values were measured. The compression for the conventional ball was measured to be 89 10 compared to the measured value of 70 for the ball of the current invention. The CoR values were 0.793 for both balls. The present invention resulted in a ball having the same resilience (CoR) and a significantly lower compression compared to a ball constructed with conventional technology.

15 EXAMPLE 6: Comparison of a Conventional Solid Core Ball to Solid Core Ball Prepared According to the Invention.

A solid core was constructed for the ball of the present invention and for a ball of conventional technology. The components and physical characteristics are presented in Table 3.

20 The cores were both created from CARIFLEX BR1220 polybutadiene starting material. One core included VAROX 231 XL and DBDB-60 (conventional technology) and the other core included a DTDS cis-to-trans catalyst of the current invention and dicumyl peroxide. The resulting solid cores had outside diameters of approximately 1.58 inches. The polybutadiene reaction product of the current invention had 25 a *trans*- isomer content of 45 percent compared to the 1.5 percent *trans*- isomer of the conventional core.

An identical cover was added to both cores and the compression and CoR values were measured. The compression for the conventional ball was measured to be 91 30 compared to the measured value of 48 for the ball of the current invention. The CoR values were 0.791 for both balls. The present invention resulted in a ball having the same resilience (CoR) and a significantly lower compression compared to a ball constructed with conventional technology.

35 EXAMPLES 7-10: Comparison of Conventional Golf Balls With Those Prepared According to the Invention.

A polybutadiene reaction product according to the invention was prepared according to the following recipe:

REACTION PRODUCT	Example 7 (Prior Art)	Example 8 (Prior Art)	Example 9	Example 10
polybutadiene rubber (CARIFLEX BR1220)	100 phr	100 phr	100 phr	100 phr
Zinc Oxide (ZnO)	26.6 phr	2.67 phr	26.6 phr	26.6 phr
Barium Sulfate (BaSO ₄)	--	31 phr	--	--
zinc diacrylate	20 phr	22.3 phr	20 phr	20 phr
dicumyl peroxide	2 phr	--	2 phr	2 phr
VAROX 802 40KE-HP ^a	--	0.89 phr	--	--
Polymeric sulfur	0 phr	0 phr	0.25 phr	0 phr
Elemental sulfur	0 phr	0 phr	0 phr	0.25 phr
Pre-cure trans-polybutadiene content	1.5 %	1.5 %	1.5 %	1.5 %
GOLF BALL CORE				
Post-cure trans-polybutadiene content in reaction product	1.5 %	1.5 %	12 %	12 %
Atti Compression	53	23	26	21
Coeff. of Restitution ("COR")	N/A ^b	0.72	0.77	0.76

^aA di-(2-t-butylisopropylperoxy)-benzene peroxide commercially available from R.T. Vanderbilt of Norwalk, CT.

^bThe core of Example 7 was sufficiently rigid to crack during testing of the coefficient of restitution, indicating an undesirably low COR.

These constituents were mixed and molded, thereby converting a percentage of *cis*- to a *trans*- conformation, in a solid sphere sized like the core of a golf ball. The compression and coefficient were measured for these cores, each having a 1.580 inch diameter. Examples 9-10 illustrate the significant conversion of *cis*-polybutadiene to *trans*-polybutadiene when a sulfur *cis*-to-*trans* catalyst is present according to the invention compared to the lack of conversion in Examples 7-8 when no sulfur catalyst is present. Moreover, Examples 9-10 illustrate the improved coefficient of restitution with no significant change in compression that can be achieved with golf balls including the reaction product according to the invention.

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The invention described and claimed herein is not to be limited in scope by the specific embodiments herein disclosed, since these embodiments are intended as

illustrations of several aspects of the invention. Any equivalent embodiments are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims.

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THE CLAIMS

What is claimed is:

1. A golf ball having a single-layer, dimpled cover disposed about a core, which golf ball comprises a material formed from the conversion reaction of a sufficient amount of polybutadiene, a free radical source, and a cis-to-trans catalyst comprising at least one organosulfur component, which reaction occurs at a sufficient temperature to form a polybutadiene reaction product, which golf ball comprises:
 - 5 an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction; and
 - 10 a cis-to-trans catalyst comprising at least one organosulfur component, wherein the reaction product comprises a sphere which has a midpoint having a first hardness and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness.
- 15 2. The golf ball of claim 1, wherein the golf ball comprises a cover having at least one of a dimple coverage of greater than about 60 percent, a hardness from about 35 to 80 Shore D, or a flexural modulus of greater than about 500 psi, and wherein the golf ball has at least one of a compression from about 50 to 120 or a coefficient of restitution of greater than about 0.7.
- 20 3. The golf ball of claim 1, wherein the reaction product has a first dynamic stiffness measured at -50°C that is less than about 130 percent of a second dynamic stiffness measured at 0°C.
- 25 4. The golf ball of claim 1, wherein the organosulfur component comprises at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido diphenyl disulfide.
- 30 5. The golf ball of claim 4, wherein the organosulfur component comprises 4,4'-ditolyl disulfide.
- 35 6. The golf ball of claim 1, wherein the cis-to-trans catalyst is present in an amount sufficient to produce the polybutadiene reaction product so as to contain at least about 32 percent *trans*-polybutadiene isomer.
7. The golf ball of claim 6, wherein the cis-to-trans catalyst is present in an amount from about 0.1 to 25 parts per hundred of polybutadiene.

8. The golf ball of claim 7, wherein the cis-to-trans catalyst is present in an amount from about 0.1 to 12 parts per hundred of polybutadiene.

9. The golf ball of claim 1, wherein the cis-to-trans catalyst further comprises at least one of an inorganic sulfur compound, an aromatic organometallic compound, a metal-organosulfur compound, tellurium, selenium, elemental sulfur, a polymeric sulfur, or an aromatic organic compound.

10. The golf ball of claim 1, wherein the polybutadiene reaction product comprises less than about 7 percent vinyl isomer content based on the total polybutadiene.

11. The golf ball of claim 10, wherein the polybutadiene reaction product comprises less than about 4 percent vinyl isomer.

12. The golf ball of claim 11, wherein the polybutadiene reaction product comprises less than about 2 percent vinyl isomer.

13. The golf ball of claim 9, further comprising a vulcanization accelerator.

20 14. The golf ball of claim 13, wherein the vulcanization accelerator comprises at least one of sulfenamide, thiazole, dithiocarbamate, thiuram, xanthate, thiadiazine, thiourea, guanadine, or aldehyde-amine.

25 15. The golf ball of claim 13, wherein the accelerator is present in an amount from about 0.05 phr to 2 phr.

16. The golf ball of claim 15, wherein the accelerator is present in an amount from about 0.1 phr to 1 phr.

30 17. The golf ball of claim 1, wherein the reaction product is disposed in at least a portion of the core.

35 18. The golf ball of claim 1, wherein the golf ball comprises:
a core comprising a center and at least one intermediate layer; and
a cover disposed concentrically about the core, wherein the reaction product is disposed in a portion of the core.

19. The golf ball of claim 18, wherein the portion of the core having the reaction product is the center.

20. The golf ball of claim 18, wherein a portion of the center comprises a fluid.

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21. The golf ball of claim 18 wherein the at least one intermediate layer comprises a wound layer of tensioned elastomeric material.

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22. The golf ball of claim 21, wherein the tensioned elastomeric material comprises the reaction product.

23. The golf ball of claim 1, further comprising a density-modifying filler.

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24. A golf ball having a core with at least two layers and a cover having at least two layers disposed about the core, which golf ball comprises a material formed from the conversion reaction of a sufficient amount of polybutadiene, a free radical source, and a cis-to-trans catalyst comprising at least one organosulfur component, which reaction occurs at a sufficient temperature to form a polybutadiene reaction product, which golf ball comprises:

an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction; and

a cis-to-trans catalyst comprising at least one organosulfur component, wherein the reaction product comprises a sphere which has a midpoint having a first hardness and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness.

25. The golf ball of claim 1, wherein the organosulfur component comprises at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido 30 diphenyl disulfide.

26. A method for forming a golf ball having a single-layer, dimpled cover disposed about a core, which golf ball comprises:

35 combining (a) a cis-to-trans catalyst comprising at least one organosulfur component; (b) a free radical source; and (c) a first resilient polymer component comprising a *cis*-polybutadiene component present in an amount greater than about 70 percent of the total polymer component;

converting a portion of the first resilient polymer component to a second resilient polymer component in about 5 to 18 minutes at a sufficient temperature to convert at least a portion of the *cis*-polybutadiene component to a *trans*-polybutadiene component and wherein the polybutadiene in the second resilient polymer component is at least about 10 percent *trans*-polybutadiene and less than about 7 percent vinyl-polybutadiene; and

5 forming the second resilient polymer component into at least a portion of the golf ball.

27. The method of claim 26, wherein the portion of the second resilient polymer component is formed into a solid sphere.

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28. The method of claim 27, which further comprises forming at least one intermediate layer and the cover over the solid sphere.

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29. The method of claim 26, which further comprises forming the portion of the second resilient polymer component into at least one layer disposed concentrically about a sphere.

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30. The method of claim 26, wherein the portion of the second resilient polymer component is formed into the cover disposed concentrically about a sphere so as to form the golf ball.

31. The method of claim 26, wherein the polybutadiene component comprises a *cis*-polybutadiene present in an amount of at least about 80 percent of the total first resilient polymer component.

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32. The method of claim 26, wherein the combining further comprises a density-modifying filler.

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33. The method of claim 26, wherein the forming comprises forming a sphere having a midpoint having a first amount of *trans*-polybutadiene and a surface having a second amount of *trans*-polybutadiene, wherein the first amount is at least about 6 percent less than the second amount.

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34. The method of claim 26, wherein the second amount of *trans*-polybutadiene component is selected to comprise a vinyl polybutadiene component present in an amount of less than about 4 percent of the total resilient polymer component.

35. The method of claim 26, wherein the organosulfur component comprises at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido diphenyl disulfide.

5 36. The method of claim 35, wherein the at least one organosulfur component comprises 4,4'-ditolyl disulfide.

37. The method of claim 26, wherein the cis-to-trans catalyst is present in an amount from about 0.1 to 25 parts per hundred of the total resilient polymer component.

10 38. The method of claim 37, wherein the cis-to-trans catalyst is present in an amount from about 0.1 to 12 parts per hundred of the total resilient polymer component.

15 39. The method of claim 38, wherein the cis-to-trans catalyst is present in an amount from about 0.1 to 8 parts per hundred of the total resilient polymer component.

20 40. The method of claim 26, wherein the cis-to-trans catalyst is selected to further comprise at least one of an inorganic sulfide, an aromatic organometallic compound, a metal-organosulfur compound, elemental sulfur, a polymeric sulfur, or an aromatic organic compound.

41. The method of claim 40, which further comprises providing an accelerator in an amount sufficient to facilitate cis-to-trans conversion.

25 42. The method of claim 41, wherein the accelerator is selected to comprise at least one of sulfenamide, thiazole, dithiocarbamate, thiuram, xanthate, thiadiazine, thiourea, guanidine, or aldehyde-amine.

30 43. The method of claim 41, wherein the accelerator is provided in an amount from about 0.05 to 2 phr of the total resilient polymer component.

44. The method of claim 43, wherein the accelerator is provided in an amount from about 0.1 to 1 phr of the total resilient polymer component.

35 45. The method of claim 29 wherein a portion of the sphere comprises a fluid.

46. The method of claim 29 wherein a tensioned elastomeric material is wound about the sphere.

47. The method of claim 46, wherein the tensioned elastomeric material comprises the reaction product.

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48. The method of claim 26, wherein the forming comprises:
a single-step compression molding of the first resilient polymer component to convert the first resilient polymer component to the second resilient polymer in about 8 to 15 minutes; and

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forming the second resilient polymer component into a solid sphere.

49. The method of claim 48, wherein the converting and forming are substantially simultaneous.

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50. A golf ball having a single-layer, dimpled cover disposed about a core, wherein the golf ball is prepared by a process which comprises:

combining (a) at least one of a cis-to-trans catalyst comprising at least one organosulfur component; (b) a free radical source; and (c) a first resilient polymer component comprising a *cis*-polybutadiene component present in an amount greater than about 70 percent of the resilient polymer component;

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converting a portion of the first resilient polymer component to a second resilient polymer component in about 5 to 18 minutes, wherein at least a portion of the *cis*-isomer content is converted to a *trans*-isomer content and wherein the polybutadiene in the second resilient polymer component is at least about 10 percent *trans*-polybutadiene and less than about 7 percent vinyl-polybutadiene; and

forming the second resilient polymer component into at least a portion of the golf ball.

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51. A golf ball having a single-layer, dimpled cover disposed about a core, wherein the golf ball comprises a material formed from the conversion reaction of a sufficient amount of polybutadiene, a free radical source, and a cis-to-trans catalyst comprising at least one organosulfur component, which reaction occurs at a sufficient temperature to form a polybutadiene reaction product, which golf ball comprises:

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an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction; and

a *cis*-to-*trans* catalyst comprising at least one organosulfur component, wherein the reaction product has a first dynamic stiffness measured at -50°C that is less than about 130 percent of a second dynamic stiffness measured at 0°C.

5 52. A method for forming a golf ball having a single-layer, dimpled cover disposed about a core, which method comprises:

10 combining (a) a *cis*-to-*trans* catalyst comprising at least one organosulfur component; (b) a free radical source; and (c) a first resilient polymer component comprising a *cis*-polybutadiene component present in an amount greater than about 70 percent of the total polymer component;

15 10 converting a portion of the first resilient polymer component to a second resilient polymer component in about 5 to 18 minutes at a sufficient temperature to convert at least a portion of the *cis*-polybutadiene component to a *trans*-polybutadiene component and wherein the polybutadiene in the second resilient polymer component is at least about 10 percent *trans*-polybutadiene and less than about 7 percent vinyl-polybutadiene; and

15 15 forming the second resilient polymer component into at least a portion of the golf ball, wherein the second resilient component comprises a sphere which has a midpoint having a first hardness and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness.

20 53. A method for forming a golf ball having a single-layer, dimpled cover disposed about a core, which method comprises:

25 combining (a) a *cis*-to-*trans* catalyst comprising at least one organosulfur component; (b) a free radical source; and (c) a first resilient polymer component comprising a *cis*-polybutadiene component present in an amount greater than about 70 percent of the total polymer component;

30 25 converting a portion of the first resilient polymer component to a second resilient polymer component in about 5 to 18 minutes at a sufficient temperature to convert at least a portion of the *cis*-polybutadiene component to a *trans*-polybutadiene component and wherein the polybutadiene in the second resilient polymer component is at least about 10 percent *trans*-polybutadiene and less than about 7 percent vinyl-polybutadiene; and

35 30 forming the second resilient polymer component into at least a portion of the golf ball, wherein the second resilient component has a first dynamic stiffness measured at -50°C that is less than about 130 percent of a second dynamic stiffness measured at 0°C.

35 54. A golf ball comprising a material formed from the conversion reaction of a sufficient amount of polybutadiene, a free radical source, and a *cis*-to-*trans* catalyst comprising at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-

benzamido diphenyl disulfide, which reaction occurs at a sufficient temperature to form a polybutadiene reaction product, which golf ball comprises:

an amount of *trans*-polybutadiene greater than the amount of *trans*-polybutadiene present before the conversion reaction; and

5 a cis-to-trans catalyst comprising at least one of 4,4'-diphenyl disulfide, 4,4'-ditolyl disulfide, or 2,2'-benzamido diphenyl disulfide.

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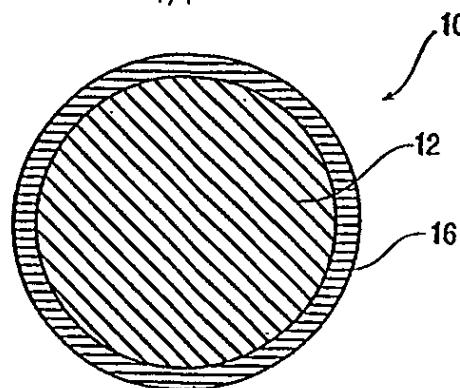


FIG. 1

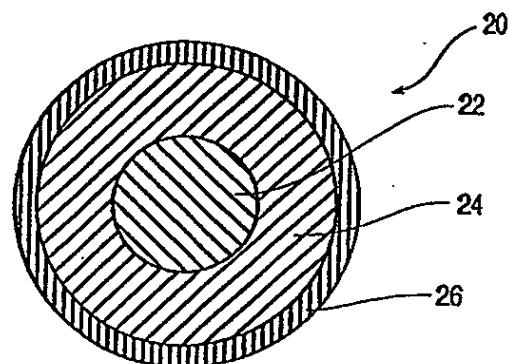


FIG. 2

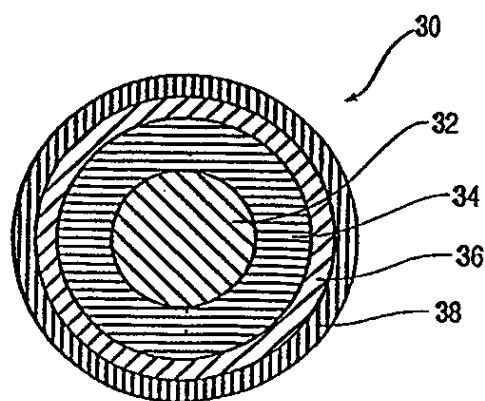


FIG. 3